Background and Ongoing Research Projects in Caltrans Retrofit Program

The 1971 San Fernando earthquake exposed a number of deficiencies in the bridge design specifications of that time. These deficiencies have the potential to impact dramatically on transportation lifelines and the travelling public today. Bridge design specifications were immediately modified to correct the deficiencies for new designs. Existing structures however, have served to be a substantially more challenging problem.

It is Caltrans philosophy to first retrofit those structures which are at greatest risk and are the most vital. The ultimate goal is to see that all of the bridges in the state are capable of surviving maximum credible earthquakes. Some damage is inevitable, but collapse is believed to be preventable with proper retrofitting. In some cases, such as Terminal Separation, an added safety factor is applied to the new design to ensure continuous serviceability of the bridge in a seismic event.

The Seismic Retrofit Program was initiated immediately after the 1971 San Fernando earthquake. Its initial objective was to ensure continuity at all superstructure joints in the state highway system bridges which are susceptible to large ground accelerations. Some typical methods used were to add restraining cables or rods at joints and hinges and to add shear keys at bearing supports. This effort was completed in 1987 after approximately 1,300 bridges had been retrofitted at a cost of over $55 million.

In 1987 additional funds were appropriated for the Seismic Retrofit Program. These financed an effort by the Division of Structures in which entire structures were subject to modification to reduce the likelihood of catastrophic failure during a large earthquake. Special attention was being focused on substructure improvements for the highest risk structures possessing single column bents. The Loma Prieta Earthquake resulted in this program being greatly accelerated through legislation. All 25,000 publicly owned bridges must be reviewed for seismic resistance to collapse. All vulnerable bridges must be retrofit. Also, as a result of the Loma Prieta Earthquake, Caltrans has received added direction from the Governor's Board of Inquiry and from Structural Seismic Review Engineers relative to improving seismic retrofit design criteria.

A number of structure modifications are currently accepted as standards in the Seismic Retrofit Program. Superstructure retrofit techniques which have proven successful during recent earthquakes will be used again to effectively force super-

structures to behave more like a single unit. The problems associated with preventing the type of substructure failures seen at San Fernando are considerably more complicated. If all columns are made to equally carry earthquake loads, then so must the footings and pile groups. This is usually not an economical solution. The preferred solution is to allow some column ends to release fixity (i.e., pin) while selective retrofitted columns and the abutments attract a greater share of forces, combining to prevent total collapse. The extent of the retrofit is a balance between economical, practical, and technical considerations.

Caltrans design engineers have been assigned the task of assessing each bridge's needs for seismic retrofitting. This may require an engineer to analyze and evaluate a structure's response well beyond its linear-elastic range. Typical bridge design offices do not have access to the non-linear analysis tools necessary for such tasks, nor are they practical to use. At Caltrans, these tools are being developed and/or installed, but it will not be an immediate effort. In order to implement the accelerated bridge retrofit schedule a design procedure has been developed which employs techniques to reasonably consider inelastic behavior.

Nonlinear Analysis of major critical bridges and retrofit solutions are being evaluated by researchers at universities throughout California. The conclusions drawn from these research projects will be used to enhance current retrofit design schemes.

A partial list of past and current research contracts include the following:

1. Seismic Modelling of Deep Foundations, Report No. UCB/EERC-84/19, 1984.

2. Structure-Foundation Interactions Under Dynamic Loads, Report No. UCB/EERC-84/18, 1984.

3. Full-Scale Experimental Testing of Retrofit Devices Used for Reinforced Concrete Bridges, Report No. UCLA/EQSE-87/01, 1987.

4. Inelastic Behavior of Full-Scale Bridge Columns Subject to Cyclic Loading, NIST Building Series 166, 1989.

5. Retrofitting of Bridge Columns (U.C.S.D.).

6. Seismic Retrofit of Bridge Column Footings (U.C.S.D.).

7. Evaluation and Retrofitting of Multi-Level and Multiple Column Structures (U.C.B.).

8. Guidelines for Effective Use of Nonlinear Structural Analysis for Bridge Structures (U.C.B.).

9. Experimental Testing of Epoxy Injected Steel Shell Retrofitted Sections from the Collapsed Struve Slough Bridge (U.C.D.).

10. Shear Strength Capacity vs. Rotation of Column Pins at Base of Elevated Roadway Structures (U.C.I.).

11. Evaluation of Dumbarton Bridge Response in the Loma Prieta Earthquake (U.C.B.).

12. Seismic Response of Deep Soil Sites in the San Francisco Bay Area (U.C.B.).

13. Evaluation of the Performance of Bridge Cable Restrainers During the Loma Prieta Earthquake (U.N.R.).

14. Seismic Condition Assessment of the Bay Bridge (U.C.B.).

15. Development of High Strength Fiber Composite Column Wrap (Fyfe Assoc., Inc.).

16. Reduced Scale Tests of Pier Walls Under Cyclic Loading for Seismic Retrofit (U.C.I.).

17. Experimental Measurements of Bridge Abutment Behavior: Stiffness, Damping and Ultimate Strength Characteristics (U.C.D.).

18. Full Scale Box Girder Column Bar Development (#18) and Cap Joint Shear (U.C.S.D.).

19. Abutment Modelling and Input Procedures for STRUDL (U.S.C.).

20. Outrigger Knee Joint Retrofits (U.C.B. and U.C.S.D.).

21. Field Tests of Lead-Rubber Isolation Bearings at 24/680 Interchange (U.C.B.).

22. Destructive Lateral Load Tests on Steel Bearings at Strawberry Underpass (U.N.R.).

23. Alternative Column Flare Details (U.C.S.D.).

Appropriate memos will continue to be routed to advise designers of latest developments.